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GB 1403363
GB 1308731
GB 1292761
GB 1236062
GB 830963
GB 810502
GB 793620
GB 483454
GB 389352
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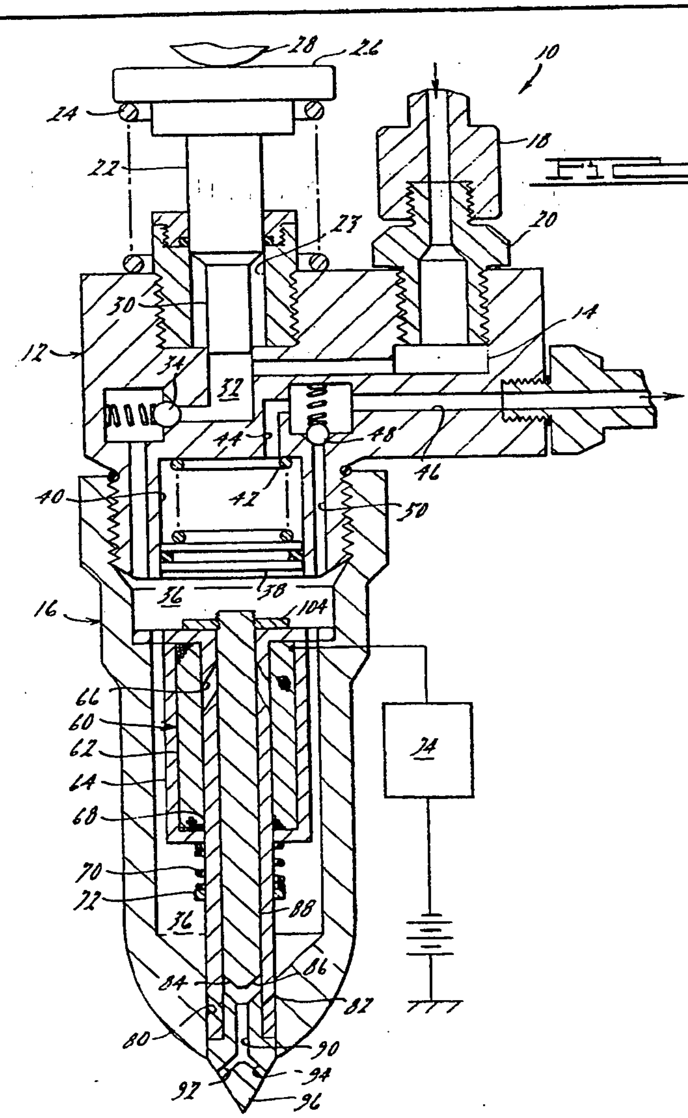
(54) Fuel Injection System for Internal Combustion Engine

(57) The system has a fuel injector (16) arranged precisely to meter fuel and accurately to time the start and, preferably, duration of fuel injection in response to a multiplicity of engine operating parameters through a control means (74) which controls energisation of a solenoid (6) to control opening of a valve (68, 84, 86) leading from an accumulator chamber (36) pressurised by an independent pump (30).



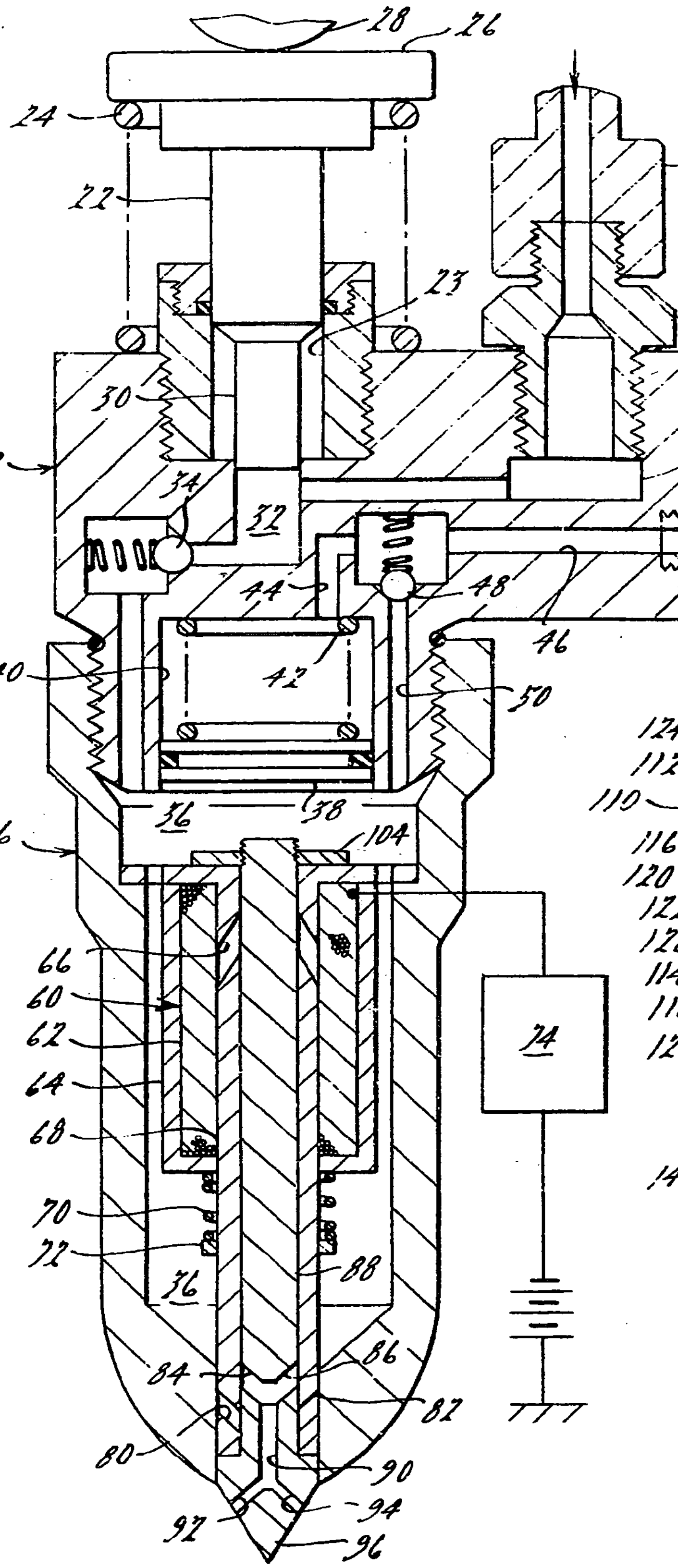

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FIG. 1.

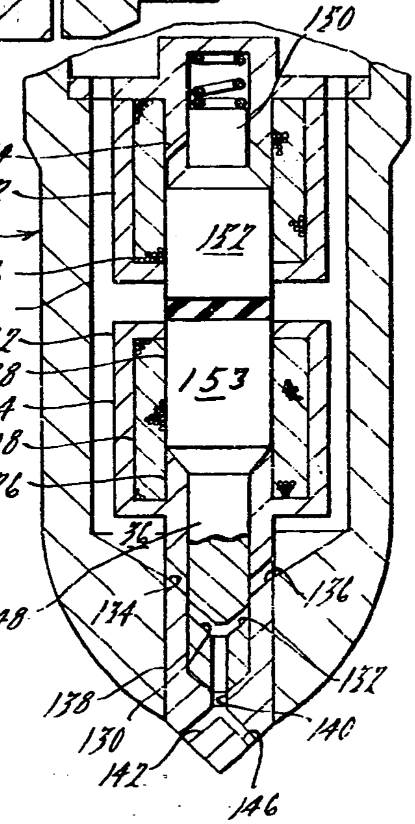
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FIG. 2.

SPECIFICATION

Fuel Inj cti n System for Internal Combustion Engine

This invention relates to a fuel injection system for an internal combustion engine.

Internal combustion engines are subject to variations in power output, smoothness of operation, economy, emissions, etc. incident to variations in fuel-air ratio, unequal distribution of fuel-air mixture to each combustion chamber, the timing of ignition in relation to the position of the piston in the cylinder, acceleration and deceleration transients, the type and amount of fuel provided, as well as external operating parameters, for example, engine load, operating speed and ambient air pressure and temperature. In addition to the foregoing parameters, compression ignition engines are faced with the functional need for initial injection of fuel during the compression stroke. Accordingly, the high gas pressure developed in the combustion chamber prior to the start of injection inhibits injection requiring fuel to be injected at a relatively higher pressure. High fuel pressure is typically achieved by pumping fuel from a low pressure rotary or gear pump to a high pressure pump. High pressure pumps may utilize rotary, displacement, or other means to pressurise fuel. A typical high pressure pump comprises a positive displacement piston driven by a cam mounted on an engine-driven camshaft. The camshaft is connected by various means, such as gears, chains, rocker-arms, cams and follower assemblies to the engine crankshaft. Other known means of pressurising fuel include electrical, mechanical, hydraulic, and electro-mechanical pump systems which separately, or in combination, develop sufficient fuel pressure to open a valve assembly which in turn injects the fuel into the combustion chamber.

Since compression-ignition occurs at a variable point in time subsequent to injection, the efficiency of the pressure-temperature build-up within the combustion chamber during the compression and expansion cycle in relation to crankshaft position and the consequent useful energy output is sensitive to many variables not the least of which is timing and duration of injection. Present compression-ignition engine fuel injection systems typically rely on direct coupling of the timing mechanism controlling fuel injection to the engine crankshaft by means of said gearing, chains and cams. In most cases, fuel injection timing is relatively fixed in terms of crankshaft position, notwithstanding that some variation in the timing of fuel injection in terms of crankshaft position can be achieved by mechanical movements or mechanisms which align relief ports or entry ports or both. It is also known to use h lical flow paths on the fuel injector plunger shaft which can be rotated adjustably to meter fuel and/or control timing by selective alignment of the fuel entry port and/or fuel relief port. In other prior devices, mechanical levers or other mechanisms open or close fuel entry or relief ports to accomplish fuel injection metering and timing.

Thus, a need exists for a fuel injection system that is capable of precisely controlling and varying the timing and duration of fuel injection in relation to crank angle, as well as having the capability of precisely metering the proper quantity of fuel, in response to the totality of operating conditions.

With respect to metering, most known direct injection systems effect filling of a cavity upstream of the injector nozzle with the exact amount of fuel to be injected. The fuel in the cavity is acted upon by a piston to provide the pressure necessary for injection.

In distribution type injectors, either rotary, displacement, or other means are used to pressurise fuel at which time a selector mechanism directs the high pressure fuel to remote injectors at or near each combustion cylinder. The high pressure fuel flows to each injector nozzle causing the nozzle to open and to inject the fuel until a subsequent pressure drop closes the nozzle. Such known systems exhibit delays and inaccuracies related to the remoteness of the pressurising means and the injection mechanism and are comparatively inefficient for controlling timing and the quantity of fuel injected.

According to the invention there is provided a fuel injection system for an internal combustion engine comprising an accumulator, means for pressurising fuel in the accumulator, a fuel injection nozzle communicating with the accumulator and adapted to communicate with the combustion chamber of the internal combustion engine with which the system is to b used, a valve for controlling the flow of fuel from the accumulator to the injection nozzle, an electric solenoid for controlling movement of the valve, and means for enerising the solenoid independently of said pressurising means in response to selected engine and environmental parameters.

In the later described preferred embodiment the pressurising means comprises a high pressure fuel pump that is not involved in the timing or metering of fuel injection or actuation of the fuel injection nozzle. Fuel injection timing can be related to a precise position of each cylinder and variations in the quantity and rate of injection are computed externally from the fuel injection mechanism by various means which include, but are not limited to, electronic, electro-mechanical, electro-magnetic, opto-electronic, piezo-electric, and other temperature, pressure, and position determining sensors, position switches and devices which measur engine operating and environmental parameters. A multiplicity of parameters involved in the combustion process can be accommodated. These include, but are not limited to, crankshaft position, engine speed, temperature of the ambient air, coolants, fuel, exhaust, and oil, fuel and air pressures, load, engine torque, vehicle speed, transmission and throttle position, fuel-air ratios, combustion

pressures, combustion temperatures, combustion air-mass flow and supercharger pressures.

Moreover, it is contemplated that memory devices, such as random-access-memories (RAMS) and/or read-only-memories (ROMS), can be utilized to store either computed data (in the instance of RAMS) or can be programmed (in the instance of ROMS) to reflect changes in injection timing, meter fuel quantity, or rate of flow of metered fuel for a multiplicity of operating conditions. Furthermore, it is contemplated that merely a change in a programmed memory can r nder a single injection device usable in different engines.

By incorporating the accumulator along with its associated pressure relief and other valving which operates to dispense fuel directly to the engine combustion chamber, means is provided to utilize very high fuel injection pressures and fuel injecting pressures which can be varied quickly, almost instantaneously and without delay. These f atures facilitate improvements in fuel economy and engine operating efficiencies and design improvements in injection spray mechanisms as well as shorter periods of fuel injection, not heretofore practical.

More particularly, the armature of an electromechanical solenoid is later illustrated as utilized as a direct fuel injection control device. The armature is not affected by high fuel pressure heads or dynamic shut-off forces. By virtue of its immersion in fuel, it is self lubricating, cooled and dynamically dampened to inhibit undesirable vibration modes.

The armature may utilize electromagnetic, spring, or other restoring forces. Since the mechanism does not affect pressurisation of the fuel, electromagnetic force and speed requirements need only be proportioned to the operating requirements of the engine, for example, in a sophisticated application, to change the rate of opening of the injection orifice, or in its most simple application, to effect only an "open-close" action. In a preferred embodiment of the invention, the electromagnetic solenoid is housed internally of the fuel accumulator of the injector. In another form of the invention, the solenoid may be disposed externally of the pressurised fuel in the accumulator. More than one electromagnetic solenoid may be utilized either to amplify the forces on the armature, eliminate return springs, or to provide opposing forces to the "open" and "close" action. In some applications, more precise movement and/or speed of armature movement can be realised with more than one solenoid. A variable and controllable pressure relief valve can be connected to the high pressure accumulator so as to provide for safety, as well as allow variations in fuel quantity metering.

The invention will be further described, by way of xample, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a fuel injector embodying the invention; and

Figure 2 is a cross-sectional view, similar to a portion of Figure 1, illustrating a modified embodiment of injector utilizing a dual solenoid arrangement.

Referring to Figure 1 of the drawings, a fuel injector 10 comprises a housing 12 having a manifold 14 and a tubular barrel 16. The manifold 14 has conventional fittings 18 and 20 for the acceptance of relatively low pressure fuel into the manifold 14.

The fuel plunger 22 is slidable in a bore 23. The plunger 22 is biased upwardly, as seen in the drawings, by a plunger spring 24. The plunger 22 has a follower portion 26 that is engageable by a cam 28 on a cam shaft (not shown) of an engine (not shown).

The plunger 22 has a piston 30 at the lower end thereof which acts against fuel in a pumping chamber 32 to pressurise and pump the fuel past a check valve 34 into a plenum chamber or accumulator 36 interiorly of the barrel 16.

The manifold 14 is provided with an accumulator piston 38 that is slidably disposed in a bore 40. The piston 38 is biased downwardly as seen in the drawings, by a spring 42. The piston 38 is movable upwardly against the bias of the spring 42 to maintain fuel pressure relatively constant within the accumulator 36 upon injection of fuel into the working cylinder of an engine as will be described.

The chamber 40 is provided with a relief passage 44 that communicates with an outlet line 46 on the back side of a check valve 48. The accumulator chamber 36 has a relief passage 50 that communicates with the high pressure side of the check valve 48 to relieve pressure within the accumulator 36 above a predetermined level. In this manner, high pressure fuel is constantly flowing through the intake manifold 14, accumulator 36, through outlet line 46, outwardly of the manifold 14 to a fuel reservoir (not shown) to provide an adequate supply of fuel for injection into a working cylinder of an engine as well as to effect cooling of the injector 10.

Injection of fuel under pressure into a working cylinder by the fuel injector 10 is controlled by a solenoid 60 comprising a coil 62, a cylindrical outer casing 64, an inner pole piece 66, and a slidable cylindrical or sleeve-like armature 68. The armature 68 is biased to the normally open condition by a spring 70 which is seated on a radial shoulder 72 on the armature 68.

The solenoid 60 is controlled by a conventional electronic assembly 74, such as but not limited to suitable sensor transducers, an input-output signal conditioning section, a microprocessor or other suitable electronic processing unit, and a drive section to provide sufficient energy and timing to actuate the solenoid and/or other electromechanical device. The electronic assembly 74 senses and correlates the engine and environmental parameters discussed hereinb fore and translates them into an appropriate electrical signal to the solen id 60.

The lower end of the armature 68 is provided with a pair of transverse bores 80 and 82 which,

when aligned with complimentary bores 84 and 86 in a fixed central mandrel 88, permit flow of pressurised fuel from the plenum 36 downwardly through a central bore 90 in the mandrel 88 and outwardly through discharge passages 92 and 94 in a spray tip 96 of the injector 10. The mandrel 88 is non-magnetic to ensure magnetic efficiency. A nut 104 secures the coil 62, armature 68 and mandrel 88 together as a sub-assembly.

Referring to Figure 2, a modified injector 110 comprises a pair of opposed solenoids 112 and 114 having coils 116 and 118, cylindrical outer casings 120 and 122, pole pieces 124 and 126, respectively, and a common slidable cylindrical armature 128. The armature 128 is biased between the open and closed condition by controlled and/or selective energisation of the coils 116 and 118. Thus, control of the injector 110 can be effected by an "on-off" signal or by a "proportional" signal.

The lower end of the armature 128 is provided with a pair of transverse bores 130 and 132 which, when aligned with complimentary bores 134 and 136 in a lower tip portion 138 on the housing of the solenoid 114, permit flow of pressurised fuel from the accumulator 36 downwardly through a central bore 140 and outwardly through discharge passages 142 and 146 in the tip 138. A lower end portion 148 and an upper end portion 150 of the armature 128 are non-magnetic while centre portions 152 and 153 are magnetisable to maximise the efficiency of the solenoids 120 and 122.

From the foregoing it should be apparent that pressurisation of fuel within a plenum chamber of the injector is disassociated from timing and duration of fuel injection which are controlled solely by the energisation of a solenoid. In this manner, fuel injection can be rendered responsive to a number of parameters of engine performance which heretofore it has not been practical to integrate into the injector control function.

Claims

1. A fuel injection system for an internal combustion engine comprising an accumulator, means for pressurising fuel in the accumulator, a fuel injection nozzle communicating with the accumulator and adapted to communicate with the combustion chamber of the internal combustion engine with which the system is to be used, a valve for controlling the flow of fuel from the accumulator to the injector nozzle, an electric solenoid for controlling movement of the valve, and means for energising the solenoid independently of said pressurising means in response to selected engine and environmental parameters.

2. A fuel injection system in accordance with claim 1, wherein the accumulator, pressurising means, injection nozzle, valve, and solenoid are disposed in a common housing.

3. A fuel injection system in accordance with claim 1 or 2, wherein said energising means is adapted to operate responsive to a multiplicity of engine and vehicle operating parameters.

4. A fuel injection system in accordance with claim 1 or 2, wherein said energising means is operative to energise the solenoid to control injection timing responsive to a plurality of engine and vehicle operating parameters.

5. A fuel injection system in accordance with any preceding claim, wherein the energising means is adapted to control timing and duration of injection without adjustment of the pressurising means.

6. A fuel injection system in accordance with any preceding claim, wherein said pressurising means is mechanically independent of the valve.

7. A fuel injection system in accordance with claim 6, wherein the pressurising means is housed in a manifold communicating with the accumulator chamber.

8. A fuel injection system in accordance with any preceding claim, wherein two of the solenoids are provided, one opposing the other.

9. A fuel injection system in accordance with any preceding claim, which is arranged to discharge pressurised fuel by operation of the valve upon energisation of the solenoid independently of actuation of the pressurising means.

10. A fuel injection system in accordance with claim 9, wherein the frequency of operation of the pressurising means is independent of the frequency of operation of the solenoid.

11. A fuel injection system constructed and arranged to operate substantially as herein described with reference to or as illustrated in Figure 1 of the accompanying drawings.

12. A fuel injection system according to claim 11, when modified substantially as herein described with reference to and as illustrated in Figure 2 of the accompanying drawings.

13. An internal combustion engine embodying a fuel injection system as claimed in any preceding claim.

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